Reference Concentration for Shelf Sediment Transport Models

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LONG-TERM GOALS

The scientific focus of this project is to better understand and predict reference concentration above the seabed. Models of sediment transport depend on parameterization of the near-bed concentration of suspended sediment (or "reference concentration") in terms of dynamical and sedimentological measures. We will evaluate the accuracy and suitability of existing expressions for reference concentration, and based on our field investigations, provide improved definition of this important parameter.

This work will be accomplished as part of an ONR-sponsored Mine Burial Research Program. It will be coordinated with other investigators who are working together to understand the oceanographic and seafloor processes that affect bottom mines. The principal goal of this research is to develop specification of the near- bed reference concentration that is tested and supported by high-quality field measurements in shallow-water marine environments.

OBJECTIVES

- Evaluate existing formulations for reference concentration C_o and their applicability for sediment transport modeling.

- Obtain high-quality field measurements of important parameters that contribute to better understanding of C_o. These include detailed near-bed measurements of velocity profiles, suspended sediment concentrations and size distributions, and particle settling velocities.

- Determine relationships between bottom velocities and stresses in shallow-water marine environments and near-bottom suspended sediment concentrations.

- Develop an accurate expression for C_o.

APPROACH

Our approach is to carry out a carefully designed field experiment to obtain data that can be used to investigate C_o. The study site seaward of the main pier in Santa Cruz harbor, Monterey Bay, CA, was selected because of the likelihood for energetic wave conditions and the presence of a well-sorted sandy bed. Data will include, but may not be limited to, near-bottom velocity profiles, suspended sediment concentrations and sizes close to the seabed, bottom sediment sizes, and bed roughness. We

will work in collaboration with Dr. Yogi Agrawal, Sequoia Scientific Inc., and Dr. Peter Thorne, Proudman Oceanographic Laboratory, England, in carrying out the field work and post-field data analysis and interpretations. The field experiment was planned to occur over several weeks in March 2003.

Our results will be useful and included in modeling by other investigators in the Mine Burial Program who are carrying out dynamical sediment transport studies at other locations (shallow water sites on the shelf off west Florida and Martha's Vineyard, MA).

WORK COMPLETED

We conducted a pilot experiment at a coastal site off California (off the main pier at Santa Cruz, CA) in December, 2001. This experiment provided testing of new equipment and sampling techniques. Excellent data on currents and waves were gathered using a Pulse-Coherent Acoustic Doppler Profiler (PC-ADP, SonTek) and single point 3-axis Acoustic Doppler Velocimeter (ADV, SonTek), as well as sonar imagery of the seafloor using a sector-scanning sonar and a narrow-beam high-resolution bathymetric profiler (both instruments from Imagenex). The sonars resolved small-scale bedforms and small bathymetric changes at repeated intervals. During the field test the sonars were cabled to a recording station on the pier.

During the period March 4-19, 2003 we carried out the major field experiment to investigate suspended sediment dynamics off the main pier at Santa Cruz, CA. A variety of instruments were mounted on two tripod frames and deployed in about 9 m mean water depth off the seaward end of the pier using a crane truck (Figure 1). The tripods were at the same depth, but were separated spatially by about 8 m. Based on diver observations and analysis of surface sediment textures; the surface characteristics at the two tripod sites were similar. The instruments on each tripod are summarized in Table 1.

At the time of this report we continue analysis of the measurements, and have begun to integrate the various data sets from all investigators. We have completed calculations of shear stresses due to currents in the bottom boundary layer, and have begun computation of combined wave-current shear stresses. Analysis of surface sediment samples for grain size distributions is also in progress.

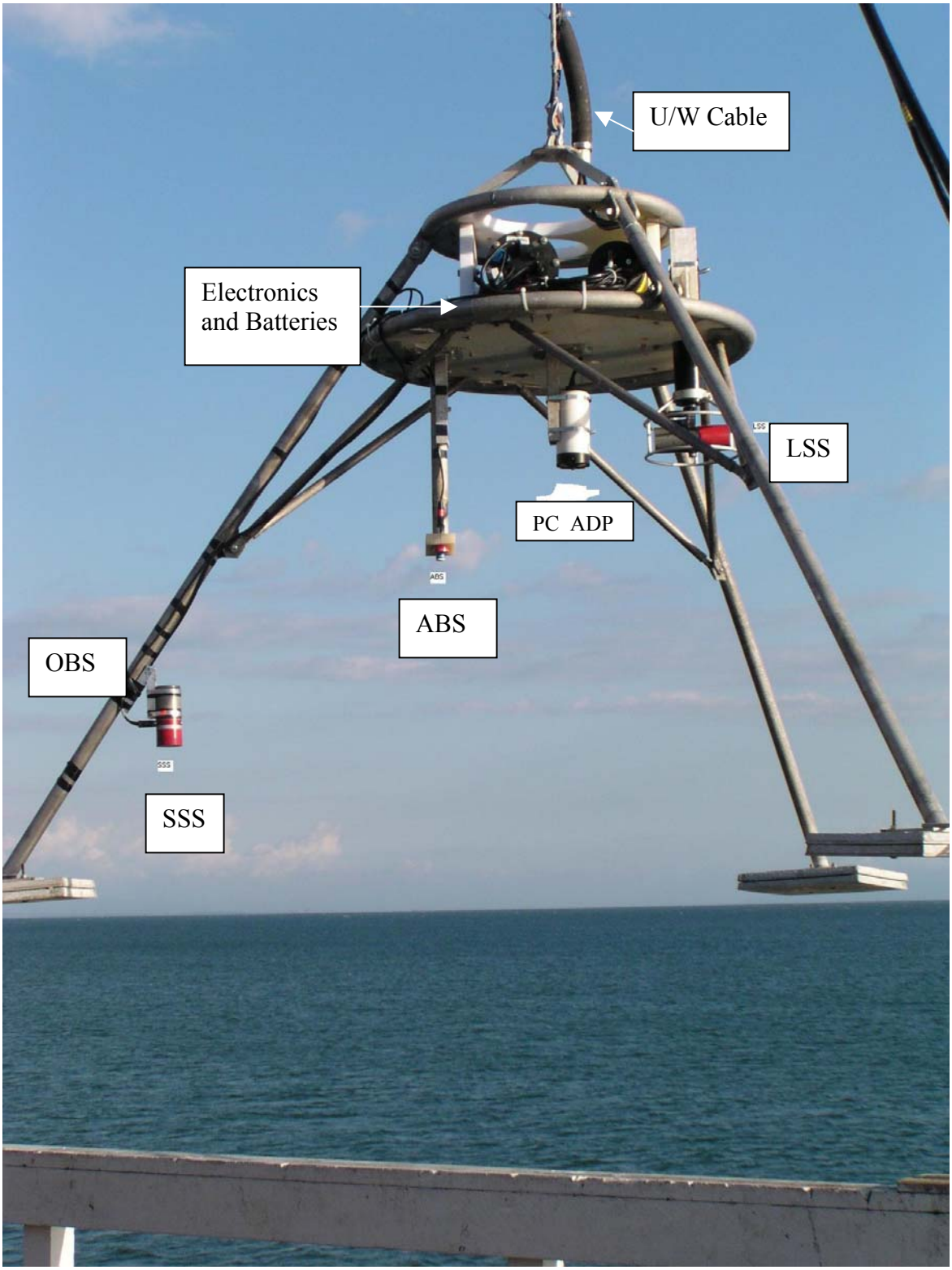

Figure 1. Instrumented tripod being launched off the main pier at Santa Cruz, CA, on March 5, 2003. Tripod weighs about 350 kg in air, and is about 2.4 m high (from base to lifting point). SSS is Sector-Scan Sonar; LSS is Line-Scan Sonar; OBS is Optical Backscatter Sensor; PC-ADP is Acoustic Doppler Profiler; ABS is Acoustic Backscatter Sensor.

Table 1. Tripod Instrumentation

Parameter ↓	Tripod A (Cacchione/Thorne)	Tripod A Sample Scheme	Tripod B (Agrawal)	Tripod B Sample Scheme
Velocity	Velocity profiles from ~ 150 cm to ~10 cm above the bottom (ab) in 3 cm vertical range bins. SonTek PC-ADP (3 velocity components and bed elevation).	Velocity components sampled at 2Hz for 10 minutes every 0.5 hr. Recorded internally and up cable on computer.		
Particle size and concentration	Concentration (and sizes) profiles over same ranges as current profiles. ABS (P. Thorne). Single point concentration measurements at 80 cm ab using one OBS.	Same as for velocity. Same as for velocity.	Particle sizes and concentrations at 20 cm, 60 cm and 110 cm ab. LISST 100 (2 levels); M-SCAT (near-bed)	40 samples at 0.5 Hz every hour.
Settling Velocity			Fall velocities for different sizes near bed. LISST-ST	Once per day.
Bottom morphology	Line-scan sonar; sector-scanning sonar	Every hour except continuous during storm.		

Note: LISST are laser particle size and concentration instruments. M-SCAT is new near-bed sensor for particle sizes and concentration. ABS is acoustic backscattering sensor that was provided by P. Thorne. ABS uses 3 transducers at different high frequencies to determine vertical profiles of particle concentrations and sizes.

RESULTS

We were fortunate to capture the effects of a moderate storm that passed through the region on 15-16 March 2003. The storm was a typical late winter event for this area characterized by southerly winds of 20-30 knots that persisted for about 2 days. The measurements indicate that the hourly-averaged currents (non-tidal) reached about 30 cm/s at 1 m above the bed during the storm. Local significant wave heights (Hs) were about 1.5 – 2.0 m; peak spectral wave periods (Tp) were about 12-15 s (Figure 2). Initial estimates of maximum bottom wave velocities (Ub) were about 80 – 100 cm/s. Changes in the morphology of the bed were observed in the sonar records. We monitored and recorded sonar images via the shore-connected electrical cable and computer work-station (housed in a van that we parked on the pier. During the storm we recorded images continuously.

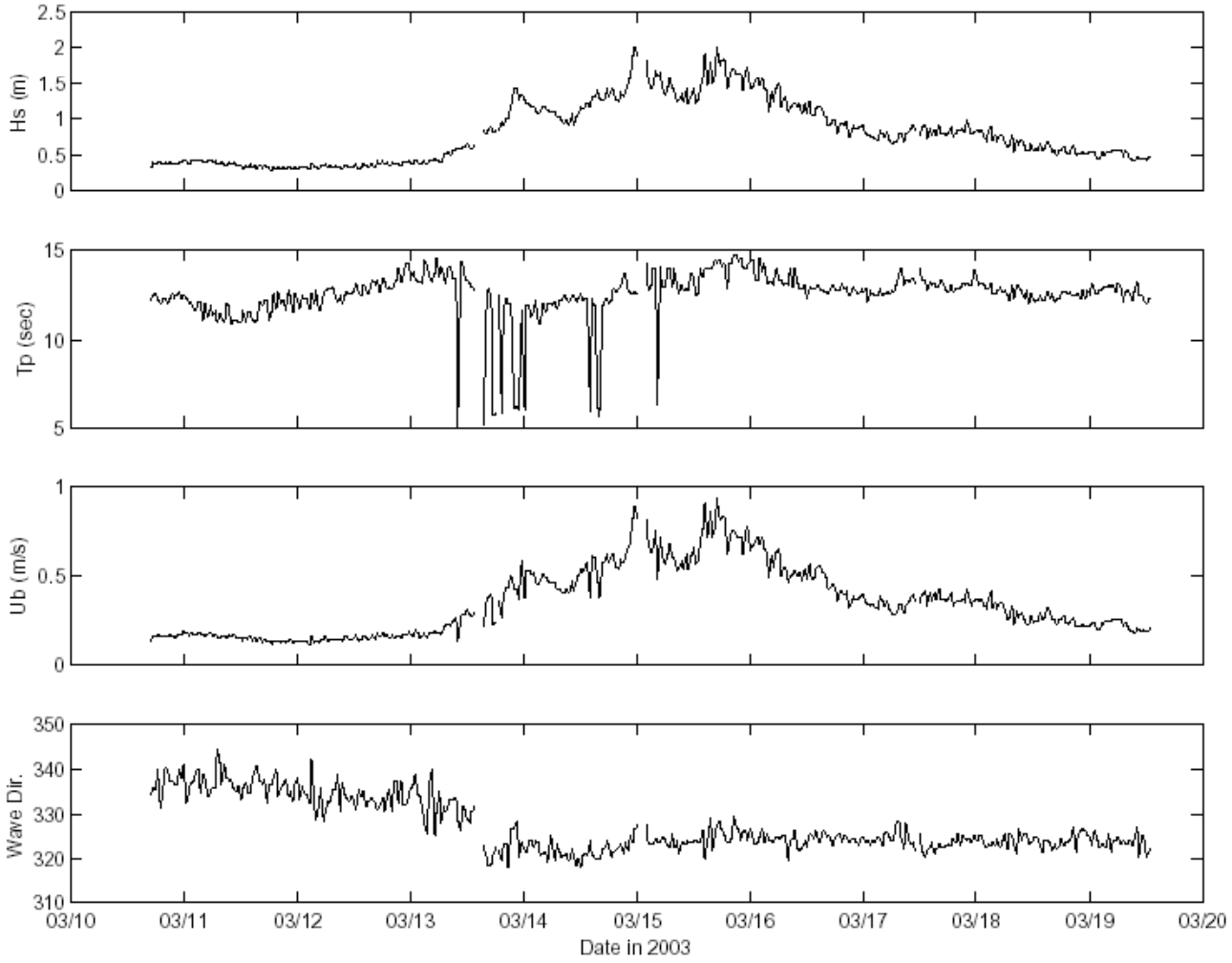

Figure 2. Wave measurements obtained with PC-ADP during experiment. Data gap on March 13 occurred during tripod recovery to repair an electrical connection.

IMPACT/APPLICATIONS

The results from the experiment will make important contributions to ongoing modeling efforts in the Mine Burial Program, and to subsequent sediment transport modeling research. We have an excellent data set to investigate the formulation of C_o, and will be able to test model representations of this important sediment dynamics parameter. Most sediment transport models that have been developed for shallow ocean conditions require specification of the relationships between bottom stresses or shears to concentrations of suspended sediment near the bed. The existing formulations have not been tested and validated under combined wave-current flow conditions above a rough bed. This work will improve this aspect of our understanding and improve modeling of sediment transport.

TRANSITIONS

This work is part of the larger ONR Mine Burial Program efforts. It will be directly integrated into the overall understanding of how mines react to physical processes in shallow water, and into improved sediment transport models.

RELATED PROJECTS

This project is directly linked to one undertaken by Dr. Yogi Agrawal, Sequoia Scientific, Inc. We will work closely on field and analysis aspects of the research. Other key collaborators are Dr. Peter Howd, U. of South Florida (USF), Dr. Peter Traykovski, Woods Hole Oceanographic Institution, Dr. Patricia Wiberg, U. of Virginia, and Dr. Carl Friedrichs, VIMS.